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WO 2000/075720 A3 US 6512626 B1
US 5317667 A US 4147932 A

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(54) Abstract Title: **Electrophoretic display device**

(57) An electrophoretic display device 2 is provided having a substrate 4 which comprises a waveguide plate and a light source 12 for side illuminating the waveguide plate. The waveguide plate generally guides light within the plane of the waveguide plate. Switching of the display to locate an electrophorectic particle 8 adjacent the waveguide substrate 4 couples light out of the waveguide which is then scattered by the particle out of the face of the substrate. The device therefore provides an emissive device that can work in low ambient lighting.

In a refinement the particles are provided with luminescent material and so luminesce when located near the waveguide substrate. Different particle may luminesce at different wavelengths to provide a multi-coloured device.

Figure 1a

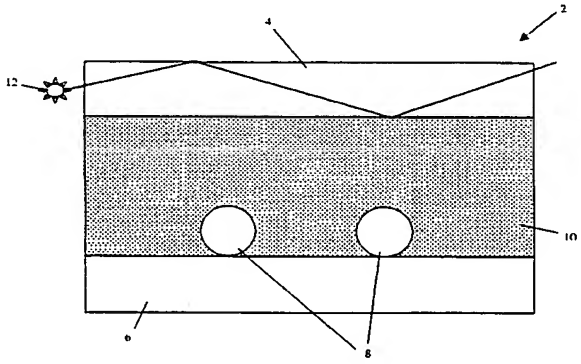

Figure 1b

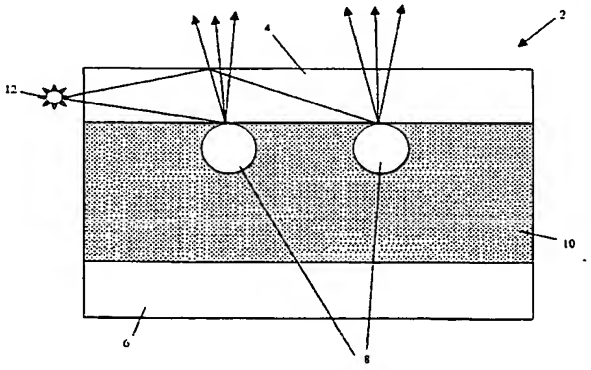

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Figure 1a

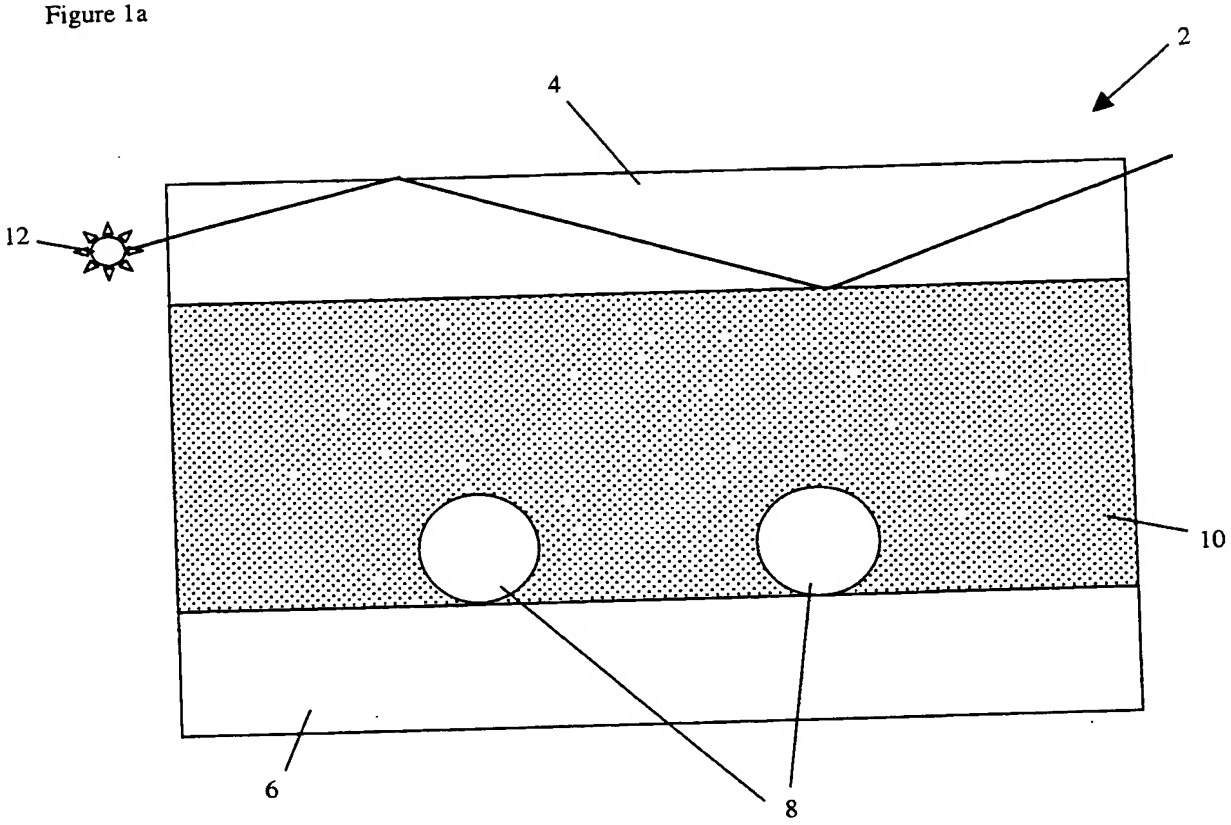


Figure 1b

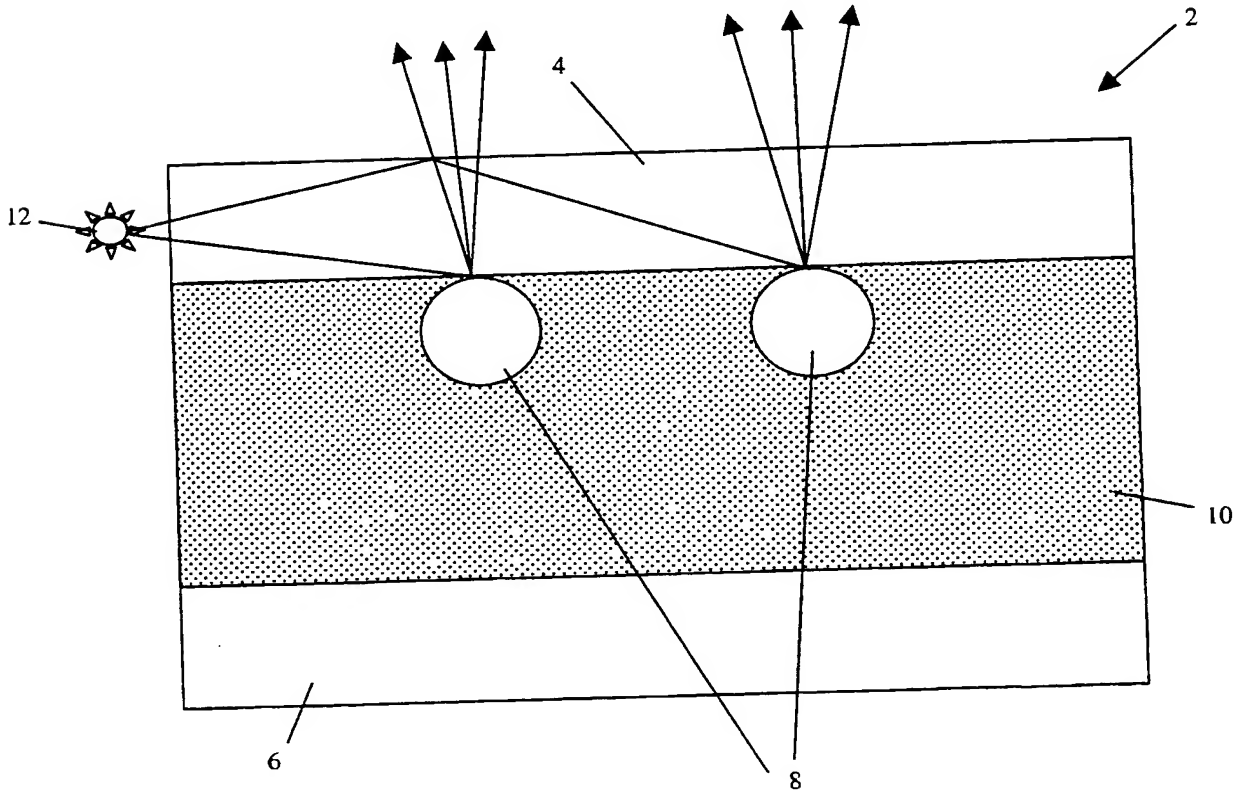
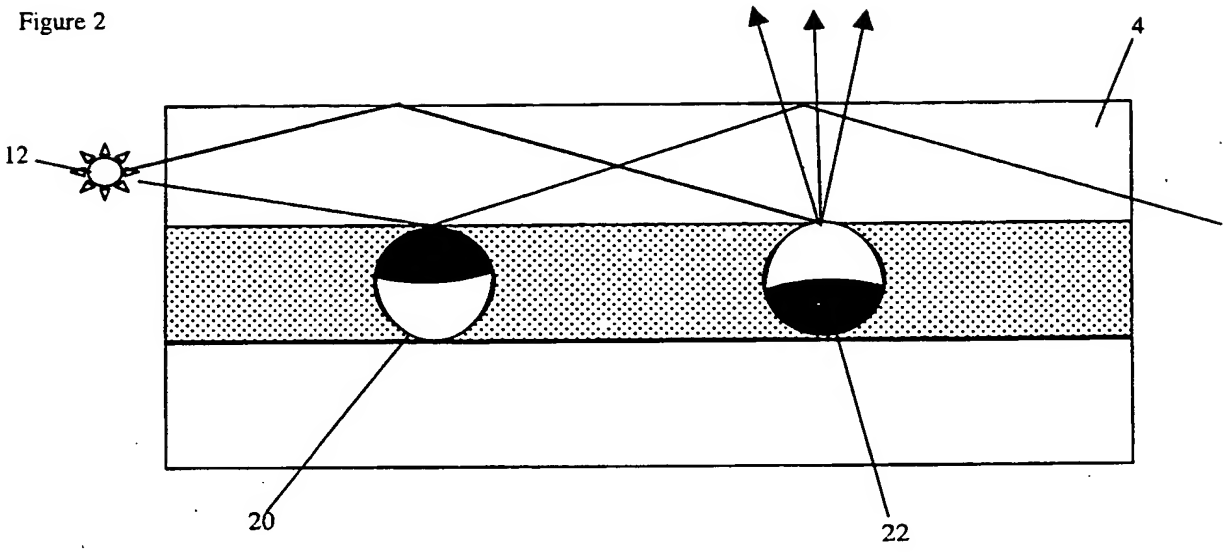


Figure 2



Electrophoretic Display Device

This invention relates to an electrophoretic display device, particularly to such a device having an illumination means.

Conventional electrophoretic displays are well known. Charged particles are suspended in a suspension medium between two substrates, at least one of which, the front of the display, is transparent. The particles and suspension medium are arranged to be different colours, for instance the particles may be white and the suspension medium black. Application of an electric field across the display will cause the particles to migrate towards either the front or the back of the display depending upon the polarity of the applied field. When a particle is located at the front of the display it displaces the suspension medium at that point and the display will appear white. When the particle is moved away however the suspension medium obscures the view of the particle and the display appears black. By dividing the display into a plurality of separately addressable pixels images can be written to the display. US patent 3,668,106 describes a conventional electrophoretic display.

Displays of this sort are inherently reflective and therefore depend upon the level of ambient light. Such displays therefore are not good for low ambient light levels. The mode of action of electrophoretic displays determines that acceptable contrast is usually only achieved under illumination from the front or viewing side of the display. Such an illumination geometry presents a number of problems including reflection of light from the front surface or intermediate layers in the device which may reduce the contrast and cause undesirable glare, and the need for light sources to be mounted or arranged to provide substantially even illumination of the display without obscuring it which may add to the bulk weight and thickness of the system.

Thus according to the present invention there is provided a display device comprising at least one electrophoretic particle in a suspension medium located between a back substrate and a transparent front substrate characterised in that at least one substrate comprises a waveguide plate for guiding light substantially within the plane of the waveguide plate and the device further comprises a light source arranged to direct light into the waveguide plate.

The present invention therefore provides the device with a waveguide plate and a light source. The waveguide plate is arranged to generally guide light in the plane of the waveguide plate. In other words, when illuminated from the side, light is guided within the waveguide plate to the other side and there is no significant emission from the face of the waveguide plate. In use then the waveguide plate is side illuminated. When the display is switched so that the electrophoretic particles are located away from the waveguide substrate the light is guided within the plate to the other side where it may be incident on an absorbing material. Thus there is effectively no emission of light from the light source from the front plate of the device. When the display is switched however so that an electrophoretic particle is adjacent the waveguide substrate the optical loss from the waveguide is effectively increased in this region. This means that light will be coupled from the waveguide and scattered by the electrophorectic particle. Therefore there will be significant emission from the display in the vicinity of an electrophoretic particle.

In order to function effectively the electrophorectic particle should preferably have a higher refractive index than the suspension medium.

It should be noted that display devices are also known where particles are disposed continuously next to the front substrate but are arranged to have at least two colours. Application of an appropriate field causes the particle to re-orientate so as to present a different colour. The present invention is equally applicable to such devices and in this specification reference to an electrophoretic display shall be taken to include reference to such devices and references to moving a particle close to the waveguide plate or away from the waveguide plate shall also be taken to mean reorientating such particle so that the part having a high refractive index is located adjacent or away from the waveguide plate respectively.

Preferably the waveguide plate has a higher refractive index than the suspension medium in order to promote optical waveguiding with low optical loss. Preferably the electrophoretic particle has a refractive index as least as high as the waveguide plate.

The present invention therefore provides a simple emissive device that can operate in low ambient lighting conditions. In high ambient lighting conditions the side illumination of the waveguide plate may not be required and the device may operate as a conventional electrophoretic device. In this case ambient light incident on the waveguide

substrate passes therethrough and is reflected or not by the particle or suspension medium appropriately.

In another embodiment the electrophoretic particle may comprise a luminescent material. In this embodiment activation of the device scatters light from the waveguide plate into the electrophoretic particle where it is absorbed. The particle can then be made to emit light at a different frequency depending upon the luminescent material employed.

Different electrophoretic particles may be provided with different luminescent materials so as to emit light at different frequencies and the particles may be arranged to provide a multicolour display. Conveniently the light source may be arranged to illuminate the waveguide plate with short wavelength radiation such as blue or ultra-violet light.

Conveniently the waveguide plate comprises the front substrate of the device. The presence or absence of an electrophoretic particle at the front substrate therefore determines whether there is scattering from the waveguide plate at that point. However in an alternative embodiment the waveguide plate could comprise the rear substrate of the device. The skilled person would realise that an appropriate electrophoretic particle could couple light from the rear substrate and direct it through the suspension medium to be emitted through the front substrate. Obviously in such an embodiment the suspension medium must be at least partially transmissive at the wavelength of operation. The invention therefore lies in ensuring the presence or absence of scattering particles adjacent a waveguide plate so as to couple light from the waveguide and out through the display surface of the device. In some embodiments it might even be desired to have waveguide plates at both the front and rear substrate.

The invention will now be described by way of example only with respect to the following drawings, of which;

Figure 1 shows an electrophoretic display device according to the present invention, and

Figure 2 shows an alternative electrophoretic display device according to the present invention.

Referring to figure 1 an electrophoretic display device is shown, generally indicated by the reference 2. The device has a transparent front substrate 4 and a rear substrate 6. Electrodes (not shown) may be located on the front and rear substrates for driving the electrophoretic display. Disposed between the front and rear substrate 4, 6 are electrophoretic particles 8 located in suspension medium 10.

Eletrophoretic particles 8 may be any conventional electophoretic particle with a relatively high refractive index such as titanium dioxide, zirconium oxide, yttrium aluminium oxide, lead sulphide, polymer latex particles or microspheres comprising polymers such as, but not limited to, poly(styrene), poly(vinyl carbazole) and poly(2-vinyl naphthalene) and compositions including such polymers together with a luminescent material such as coumarin 6, Nile red, luminescent chelates of metals including but not limited to europium, terbium, dysprosium, chromium, zinc, manganese, aluminium and iridium, phosphor materials such as (optionally doped) zinc sulphide and cadmium sulphide in particulate or nanoparticulate form, anthracene, derivatives of perylene and decacyclene. The electrophoretic particles may also comprise materials which are both luminescent and exhibit a high refractive index including zinc sulphide and other luminescent materials such as doped oxides, sulphide, garnets, germanates and spinels. Suspension medium 10 may again be any convention medium such as aliphatic alicyclic and aromatic hydrocarbon fluids and oils, ethers esters and ketone derivatives of hydrocarbons and combinations thereof together with fluorocarbon fluids and fluorocarbon ether derivatives such as the Fomblin fluids available from the Solvay Solexis company.

As will be well understood by those skilled in the art electrophoretic particles carry a charge and may be moved between the two substrates by application of an appropriate

electric field between the electrodes. Figure 1b shows the particles moved towards the front substrate.

Referring back to figure 1a the display device further comprises a light source arranged to side illuminate the front substrate 4 which in this case is the waveguide plate. The light source 12 may be any convenient light sources such as an LED or LED array or a gas discharge lamp. The skilled person would be well aware how to couple light into the waveguide plate 4.

Waveguide plate 4 may conveniently be formed from glass or a transparent plastic.

In operation light from the light source 12 is coupled into the waveguide plate. The waveguide plate has a higher refractive index than air and also a higher refractive index than the suspension medium 10. Therefore in the situation shown in figure 1a light coupled into the waveguide from the light source 12 is guided in the waveguide 4 with low loss to the other side where it is either allowed to escape the device, reflected back into the waveguide or absorbed.

Figure 1b shows the situation when the electrophoretic particles are moved close to the front substrate 4. In the vicinity of the particles 8 the light no longer experiences a waveguide/suspension medium interface but a waveguide/particle interface. As the particle has a higher refractive index a proportion of the light will be coupled out of the waveguide where it will be scattered by the particle. Light scattered by the particle will be at a higher angle of incidence when it re-encounters the waveguide and so will be transmitted through the waveguide out of the front of the device.

Therefore any regions of the device where a particle is close to the front substrate will see light coupled out of the device whereas in the rest of the device no emission will occur.

In an alternative embodiment the electophoretic particle 8 comprise a luminescent material such as polystyrene doped with a fluorescent dye or silica doped with a rare earth such as erbium. In this case light coupled out of the waveguide is absorbed by the particle and then re-emitted at the intended wavelength. Different particles could comprise different luminescent materials with different luminescent wavelength to provide a multi-coloured device.

Figure 2 shows another type of device to which the invention can be applied. Instead of particles being moveable between two substrate bi-coloured particles 20, 22 are used that can be rotated by application of a field. The particles would then be arranged to have one side having a high refractive index and the other side having a low refractive index. The waveguide plate arrangement is the same as that described with reference to figure 1. Particle 20 illustrates the situation with the low refractive index side adjacent the waveguide and particle 22 with the high refractive index side adjacent the waveguide.

CLAIMS

1. A display device comprising at least one electrophoretic particle in a suspension medium located between a back substrate and a transparent front substrate characterised in that at least one substrate comprises a waveguide plate for guiding light substantially within the plane of the waveguide plate and the device further comprises a light source arranged to direct light into the waveguide plate.

2. A display device as claimed in claim 1 wherein the electrophoretic particle has a higher refractive index than the suspension medium.

3. A display device as claimed in claim 1 or claim 2 wherein the waveguide plate has a higher refractive index than the suspension medium.

4. A display device as claimed in any preceding claim wherein the electrophoretic particle has a refractive index at least as high as the waveguide plate.

5. A display device as claimed in any preceding claim wherein the at least one electrophoretic particle comprises a luminescent material.

6. A display device as claimed in claim 5 wherein a plurality of electrophoretic particles are provided and at least some particles have one of at least two luminescent materials, each luminescent material having a different wavelength of emission.

7. A display device as claimed in claim 5 or claim 6 wherein the light source is a short wavelength light source.

8. A display device as claimed in claim 7 wherein the light source is an ultraviolet light source.

9. A display device as claimed in any preceding claim wherein the waveguide plate comprises the front substrate.

10. A display device as claimed in any preceding claim wherein the waveguide plate comprises the rear substrate.

Application No: GB 0317911.6
Claims searched: All

Examiner: Helen Edwards
Date of search: 18 November 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 9	WO 00/75720 A3 (UNIVERSITY OF BRITISH COLUMBIA) See fig 5a and page 14
X	1, 10	US 6512626 B1 (CREAVIS) See figure 1 and column 3 lines 22-45 and column 7 lines 13-29
X Y	1, 9 2, 3, 4	US 4147932 (XONICS) See figure 1 and column 2 line 40 to column 3 line 17
Y	2, 3, 4	US 5317667 (FORD MOTOR COMPANY) See columns 2 and 3

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[V]:

G2F

Worldwide search of patent documents classified in the following areas of the IPC[7]:

G02F

The following online and other databases have been used in the preparation of this search report:

EPODOC, JAPIO, WPI